

*SELF-STIMULATORY BEHAVIOR AND PERCEPTUAL REINFORCEMENT*

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Self-stimulatory behavior is repetitive, stereotyped, functionally autonomous behavior seen in both normal and developmentally disabled populations, yet no satisfactory theory of its development and major characteristics has previously been offered. We present here a detailed hypothesis of the acquisition and maintenance of self-stimulatory behavior, proposing that the behaviors are operant responses whose reinforcers are automatically produced interoceptive and exteroceptive perceptual consequences. The concept of perceptual stimuli and reinforcers, the durability of self-stimulatory behaviors, the sensory extinction effect, the inverse relationship between self-stimulatory and other behaviors, the blocking effect of self-stimulatory behavior on new learning, and response substitution effects are discussed in terms of the hypothesis. Support for the hypothesis from the areas of sensory reinforcement and sensory deprivation is also reviewed. Limitations of major alternative theories are discussed, along with implications of the perceptual reinforcement hypothesis for the treatment of excessive self-stimulatory behavior and for theoretical conceptualizations of functionally related normal and pathological behaviors.

DESCRIPTORS: self-stimulatory behavior, perceptual reinforcement, reinforcement, autistic children, retardates

There exists a class of behaviors that are stereotyped and repetitive, appear in near-identical form across several members of a species, and are functionally autonomous in the sense that they can

persist indefinitely in the absence of social consequences. These behaviors take the form of prolonged body-rocking, head-nodding, flapping the hands at the wrist, tapping or shaking objects, gazing at lights, jumping up and down, etc. A recent survey found that 50 different topographies have been studied in the applied literature alone (LaGrow & Repp, 1984). Sometimes the behavior appears to produce primarily visual stimuli, as when the individual squints or rolls the eyes, twirls a string in front of the eyes, stares at lights or rotating fans, repeatedly assembles the same puzzle, or "compulsively" lines up objects on the floor. Sometimes the stimulation may be primarily vestibular, as when the person engages in body-rocking, head-nodding, or spinning while standing up. Some behaviors generate primarily tactile input, through stroking, poking, or pinching oneself, or rubbing interesting surfaces such as smooth table tops or textured sweaters. In other cases, auditory stimulation seems to be the primary source of feedback,

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as when the person taps an object on a table, repeats the same pattern of three notes, or repeatedly echoes a string of words. These behaviors may involve the body only (e.g., rocking and hand-flapping) or the manipulation of objects (tapping, shaking, or twirling). Further, the behaviors may reflect various degrees of interaction with the environment, ranging from simple gazing at lights or body-rocking to elaborate lining up of objects or repetitive assembly and reassembly of puzzles. Although the latter behaviors are more complex than simpler motor stereotypies like rocking and hand-flapping, they seem to be similar in their stereotypy, independence from socially mediated reinforcers, and ability to create patterned stimulus input.

Psychologists and ethologists, who have been studying these behaviors for some time, have referred to them as "abnormal stereotyped acts," "mannerisms," "motility disturbances," "ritualistic acts," "rhythmic habit patterns," "blindisms," or "autisms" (e.g., Baumeister & Forehand, 1973; Berkson, 1967; Mitchell & Etches, 1977). Berkson and Davenport (1962) noted that "stereotyped behaviors are self stimulatory in character" (p. 852) and we have long referred to such behavior as self-stimulatory behavior (Lovaas, Schaeffer, & Simmons, 1965). Although it is somewhat controversial (Baumeister, 1978), we will continue to use this term here because it calls attention to an important feature of these behaviors that has theoretical significance, as we intend to demonstrate.

Instances of self-stimulatory behavior are frequently observed in considerable strength in persons with severe developmental delay; more transient forms are seen in normal infants and very young children. Such behaviors may also be observed in normal adults who are experiencing stress or a temporary loss of opportunities to engage in other behavior. Many kinds of self-stimulatory behavior also appear in the repertoires of members of other species, including primates and birds, when they have been deprived (in captivity) of behaviors associated with living in their natural habitat. Berkson (1967) has provided a review of some of the variability in self-stimulatory behaviors across

species, noting that there is an increase in the number of different kinds of self-stimulatory behavior going up the phylogenetic scale.

Our own interests in self-stimulatory behaviors come from work with developmentally disabled (autistic, retarded) and schizophrenic persons, and our clinical observations over a period of many years may help to illustrate some of the tactical and conceptual problems posed by these behaviors. First, the children invariably brought into treatment a large variety of high-rate, persistent self-stimulatory behaviors, such as rocking, spinning, hand-flapping, gazing, and delayed echolalia. Because these occurred in near-identical form across children reared in diverse cultures (Asia, Latin America, Europe), and because they resisted extinction by the withdrawal of attention and other socially mediated reinforcers, it did not seem likely that they were the product of a common social reinforcement history. Second, when engaged in these behaviors, the children were particularly hard to "reach" socially and difficult to teach. Their attention seemed to focus exclusively on their own behaviors, making them oblivious to all but the strongest external stimuli. Third, the children who received extensive behavioral treatment emerged with quite novel forms of self-stimulatory behaviors. For example, as the children were taught vocal imitation (Lovaas, Berberich, Perloff, & Schaeffer, 1966), about half of the previously mute children became excessively echolalic and persisted in this behavior (Lovaas, Varni, Koegel, & Lorsch, 1977) despite our discouragement of it. Other unexpected and elaborate repertoires also developed during treatment, such as obsession with numbers, compulsive arrangement of letters, and frequent assembly and reassembly of the same jigsaw puzzle (Epstein, Taubman, & Lovaas, 1985). The children who made the largest gains in treatment were also the ones who emerged with the largest repertoire of such "personally contributed" behaviors.

To date, no comprehensive theory of self-stimulatory behavior in the developmentally disabled has been proposed. Most theorizing in this area has consisted of unelaborated accounts of specific experimental results, often focusing on body-rock-

ing as the "prototypical" self-stimulatory behavior. As a result, Baumeister (1978) found it necessary to create a five-way classification scheme simply to impose some order on the many different accounts, noting that none explained very many findings. The purpose of this paper is to present in some detail the hypothesis that self-stimulatory behavior is operant behavior that is maintained automatically by the reinforcing perceptual stimuli that it produces. This hypothesis will be used to explain the acquisition of representative behaviors and the etiology of self-stimulatory behavior in developmentally disabled persons, as well as certain prominent characteristics of self-stimulatory behavior. Empirical support for this hypothesis is offered from relevant areas of research. The Discussion considers two representative alternative theories and describes implications of our hypothesis for the treatment of developmentally disabled persons and the understanding of apparently related behaviors in other populations.

### PERCEPTUAL REINFORCEMENT HYPOTHESIS

The hypothesis that self-stimulatory behaviors are shaped and maintained by perceptual reinforcers can be stated briefly as follows: Self-stimulatory behaviors constitute a class of learned, operant behaviors for which the reinforcers are the perceptual stimuli automatically produced by the behavior. Such stimuli may be generated directly by the movements involved in the behavior or result from a particular arrangement of external stimuli produced by the behavior in interaction with its environment.

The hypothesis that self-stimulatory behavior could be learned behavior is based on the following considerations. First, many forms of self-stimulatory behavior seem so elaborate and idiosyncratic that learning variables must have entered to help shape or maintain the behaviors. For example, many autistic children repeatedly arrange (line) objects such as toys, books, or shoes in neat rows across the floor. It would be difficult to argue that such a child is born with the behavior of aligning

objects. Other self-stimulatory behaviors, such as repetitive manipulation of pieces of string and echolalic repetitions of phrases and songs, do not seem to be innate and require an explanation in terms of learning principles. If the behavior is learned, it may be an instance of operant behavior, that is, functionally related to its consequences. If it is operant, there is no convincing evidence that the behavior is shaped by social consequences. For example, attention and other socially mediated reinforcers can be withdrawn without observing a decrease in the behavior.

Second, the most reliable and inevitable consequences of self-stimulatory behaviors are the perceptual or sensory stimuli that these behaviors produce. These consequences are spatially and temporally contiguous with self-stimulatory behaviors, factors known to enhance the potency of any reinforcer. Most important, there is a considerable body of empirical evidence to support the contention that sensory and perceptual stimuli can function as reinforcing events, as reviewed later in this paper.

Finally, self-stimulatory behaviors are very high probability behaviors for many children. As such, they may be expected a priori to be reinforcing (Premack, 1965) and have in fact been shown to reinforce less probable behaviors when made contingent upon them (e.g., Hung, 1978; Wolery, Kirk, & Gast, 1985). The reinforcing function of self-stimulatory behaviors may be due to the salient perceptual consequences that they generate.

#### *Perceptual Reinforcers*

The precise characteristics of perceptual reinforcers produced by self-stimulatory behavior remain to be studied. However, certain main features, some of which distinguish them from other classes of reinforcers, appear to be the following.

First, perceptual reinforcers are not mediated by the social environment but, instead, are controlled by the individual. Note, however, that the social environment may provide some indirect control in arranging exposure to conditions necessary for the potentiation or activation of perceptual reinforcers. For example, exposure to a verbal language com-

munity is a prerequisite for echolalic speech and exposure to objects such as blocks or pieces of string is necessary for a child to come under the control of the reinforcing properties of "objects in a line" or rhythmic string movements.

Second, perceptual reinforcers are primary reinforcers in the sense that their ability to strengthen behaviors is not based on prior conditioning but ultimately on an organic function of stimulation in the central nervous system. Perceptual reinforcers also tend to be very durable or less subject to satiation than other positive reinforcers.

Third, some perceptual reinforcers exhibit what might be termed *conditional generality* across species or populations if certain preconditions are fulfilled, whereas others are largely idiosyncratic to one or a few individuals. For example, isolation rearing in chimpanzees and severe developmental disability in humans increase the likelihood that rhythmic vestibular stimulation will become a powerful reinforcer and that body-rocking will occur. In normal infants, most elementary or early forms of self-stimulatory behavior, such as hand-gazing, object-banging, and repetitive vocalizations, appear to be controlled by reinforcers that, like sex and food, are functional for the great majority of persons across all cultures. Later developing, more complex forms of self-stimulatory behavior, such as repetition of number sequences, "compulsive" spelling of words, and assembly and reassembly of the same puzzle, may be based on more complex perceptual reinforcers requiring specific kinds of environmental exposure and therefore reflecting more idiosyncrasy.

It is important to note that there are certain difficulties in achieving experimental control over some perceptual reinforcers. In the case of perceptual reinforcers based on *exteroceptive* stimulation, experimental control usually does not pose a major problem. For example, it is relatively easy to remove and reinstate stimuli such as objects, lights, sounds, etc. It would also be possible (technically, at least) to control an individual's exposure to certain complex stimuli (e.g., speech, music, visual patterns) when prior exposure to such stimuli is

necessary for their potentiation as perceptual reinforcers. However, in the case of *interoceptive* stimuli, such experimental control may present a significant problem. To the extent that experimental control is difficult to achieve, the perceptual reinforcement hypothesis becomes less viable. The difficulty of achieving control over interoceptive stimuli may eventually result in a narrower definition of self-stimulatory behavior than the one proposed here and may necessitate that the hypothesis be limited to those forms involving exteroceptive stimuli. But for now we shall proceed on the assumption that both kinds of stimuli can reinforce self-stimulatory behaviors and we shall treat them as functionally equivalent.

Finally, we have chosen to speak of "perceptual" rather than "sensory" stimuli. The reason for doing so is partly because afferent stimulation during repetitive movement comes from multiple receptors and is relatively complex and patterned (Dickinson, 1974). Thus, even a simple self-stimulatory behavior like rocking creates rhythmically patterned kinesthetic stimulation from the trunk and vestibular stimulation from the inner ear. Further complexity occurs if the behavior produces both interoceptive and exteroceptive stimuli (e.g., kinesthetic and visual stimuli during flapping of the hands in front of the eyes). The complexity and patterning of the stimuli accompanying the performance of self-stimulatory behaviors lead us to use the term "perceptual" to describe them. The alternative, "sensory," is acceptable but less preferable because, in psychology at least, it is too frequently associated with relatively simple stimuli like those used in psychophysics. (Note also that psychology long ago split the fields of sensation and perception, partly on the basis of the differences in the complexity of stimuli studied.) The "perception" of such stimuli need not be conceptualized in cognitive terms. It is sufficient to propose that the individual discriminates (feels, sees, hears) the stimulus consequences of his or her own behavior (cf. Skinner, 1969, chap. 8). By analogy with appetitive reinforcement paradigms, these attending behaviors constitute the "consummatory"

responses by which the individual experiences the perceptual consequences of his or her self-stimulatory behaviors.

### *Acquisition of Self-Stimulatory Behaviors*

It may be helpful to illustrate, through some examples, how an individual's self-stimulatory behaviors might be acquired on the basis of perceptual reinforcers. Consider a common behavior like string twirling. An autistic child initially twirls a string in a variety of different ways. Sooner or later (through trial and error) a pattern of string movements is discovered that is particularly attractive to look at (i.e., that strongly reinforces twirling the string). With practice, he or she learns to perform exactly the right manipulation of the string to achieve the preferred pattern and tends to perform only that topography and closely related topographies most of the time. Consider another example: A child will retrieve and then skillfully manipulate a variety of objects (dishes, sink-stoppers, balls, etc.) to make them rotate or spin. Once the object comes to a resting position he or she will resume the behavioral sequence. In such an example, the child's spinning of various objects may be an acquired response, an operant, whose visual consequence (the spinning object) is the perceptual reinforcer that shapes and maintains the response. In the example of the child who repeatedly arranges (lines) objects such as toys, books, or shoes in neat rows across the living room floor, "objects in a line" may constitute a positively reinforcing perceptual consequence, shaping and maintaining the lining behavior.

The natural variability in the topographies of an individual's self-stimulatory behaviors produces qualitatively different perceptual consequences, some more reinforcing than others. The most reinforcing consequences then acquire control over an increasingly narrow range of topographies, for only certain topographies are capable of producing those consequences. Thus, the individual learns to engage in only certain topographies in order to produce the "right" (subjectively most preferred) perceptual consequences. This progressive narrowing

of topographies to a final, stereotyped form may be viewed as a self-shaping process in the same sense that, at a more complex level, an athlete or a musician engages in successively "better" topographies and discards them until achieving a topography that "feels right" or produces the "right sound." (The situation we are describing differs from shaping as it is usually understood because the same individual is both the shaping agent and emits the shaped responses. Thus, incorrect topographies are not extinguished by the withholding of reinforcement by an outside agent; they extinguish automatically because they fail to produce the preferred perceptual consequences for the individual.)

Changes in a topography beyond a certain point result in different perceptual consequences and, therefore, another response class defined by these different perceptual reinforcers. For example, banging an object on a table produces auditory, visual, tactile, and kinesthetic stimuli, but shaking it in front of the eyes may produce only visual, tactile, and kinesthetic stimuli. Similarly, hand-flapping always produces kinesthetic feedback but may also produce visual stimulation. In both examples, the topography has not changed much but the perceptual reinforcers have. The value of identifying different response classes based on slightly different perceptual reinforcers (but still within one behavior termed, e.g., "object manipulation" or "hand-flapping") is that their existence helps to explain the durability of self-stimulatory behaviors and the large amounts of time invested in a dominant behavior. The individual varies his or her self-stimulatory topographies from moment to moment because the resulting variation in perceptual feedback is more reinforcing than the unchanging feedback from a rigidly stereotyped topography would be. In other words, variability enriches what otherwise might become monotonous stimulation vulnerable to rapid satiation. Thus, the stereotypy of self-stimulatory behaviors is only relative, based on how closely these behaviors are looked at and, perhaps, who is doing the looking. What appears highly stereotyped in comparison to more "intellectual" behavior may be at a preferred level of

complexity for the severely limited individual who is engaging in the behavior.

Variability is also important in the motivation of self-stimulatory behavior at a more molar level of analysis. In addition to exhibiting a dominant behavior, most developmentally disabled individuals exhibit a greater or lesser number of other self-stimulatory behaviors (see, e.g., Koegel, Firestone, Kramme, & Dunlap, 1974, Table 1). The availability of multiple behaviors explains why an individual often continues to engage in self-stimulatory behavior even when not engaging in his or her dominant, most preferred topography. Eventual satiation on the stimulation provided by the dominant behavior or the unavailability of the dominant behavior due to, for example, a treatment intervention results in switching to a different behavior and its correlated perceptual consequences. Thus, overall satiation on perceptual stimulation need never occur as long as the person can shift from one self-stimulatory behavior to another. This appears to be an important reason why self-stimulatory behavior, as a class, is so strong and durable in many developmentally disabled persons and so difficult to eliminate entirely. (An additional reason, the lack of competing alternative behaviors, will be discussed in the following section.) Variability across similar topographies and across multiple behaviors may, therefore, not be simply "noise in the system" or "error variance" but fundamental characteristics of self-stimulatory behavior that other theories have failed to address, yet can be explained by perceptual reinforcement theory.

### *Origin and Course*

In addition to describing how particular self-stimulatory topographies might be acquired, a theory of self-stimulatory behavior should account for the ontogeny of such behavior in retarded and autistic children. Actually, because self-stimulatory behavior appears to be universal in infants (Kravitz & Boehm, 1971; Thelen, 1979), the problem is to account for the maintenance and elaboration of such behavior in severely or profoundly retarded

and autistic children and its decline in normal children.

In normal children, the course of self-stimulatory behaviors after 12 months has not yet been documented. The frequency of these behaviors begins to decline after 7 months (Thelen, 1979) as the infant, then toddler, acquires new behaviors based on social contingencies, language, and higher, age-appropriate perceptual reinforcers, such as those provided by play, toys, books, and television. However, the number of different self-stimulatory behaviors continues to increase throughout the first year (Thelen, 1979). If these trends continue, normal children and adults might be expected to show low frequencies but multiple topographies of self-stimulatory behavior. Further, it is likely that some topographies disappear but others change to more subtle and socially acceptable forms (e.g., tapping a pencil, twirling hair, and rocking only in a rocking chair). Some limited data on normal children and adults support these possibilities (Rago & Case, 1978; Zern & Taylor, 1973). Perceptual reinforcement is presumed to play a role in the selection and maintenance of the self-stimulatory behaviors displayed, but other, situational and social variables determine whether or not they will occur. Interestingly, along with the continuation of these simple self-stimulatory behaviors, normal children and adults also develop extensive repertoires of much more complex behaviors based on perceptual reinforcement, an important point we will return to in the Discussion.

The outcome is usually very different for severely or profoundly retarded and autistic children. Although the onset of their self-stimulatory behaviors may be delayed relative to normal infants (Kravitz & Boehm, 1971), such behaviors are usually very evident during the second year (Berkson, McQuiston, Jacobson, Eyman, & Borthwick, 1985; DeMyer, 1979). They may begin by following the same general developmental course as that seen in normal infants (Wolff, 1967) but persist for two main reasons. First, few alternative behaviors that might compete with them are acquired (cf. Berkson, 1967). This is simply an operational defini-

tion of "mental retardation"; an important corollary is that few normal sources of stimulation and reinforcement are functional (i.e., those inherent in play, language, and social interaction). Second, the major remaining option, doing nothing, is far less reinforcing than self-stimulatory behavior. Prolonged inactivity may even be aversive, as it seems to be for most young children and as suggested by some studies of the effects of movement restriction (including restriction of self-stimulatory movements) with older autistic and retarded children (Rolider & Van Houten, 1986; Solnick, Rincover, & Peterson, 1977). Thus, the perceptual reinforcers generated by self-stimulatory behaviors remain the most accessible and predictable reinforcers for the severely impaired child. Certain existing topographies become more frequent and intensive because they reliably produce subjectively preferred perceptual consequences. For example, body-rocking becomes more frequent and greater in amplitude (cf. Schwartz, Gallagher, & Berkson, 1986). Other topographies change form as increasing neuromuscular control and environmental exposure allow contact with new perceptual consequences discovered through trial and error. Infantile arm-waving or hand-gazing, for example, may become operant hand-flapping, and simple object manipulations may evolve into string-twirling or spinning the wheels of a toy car. Changes in early repertoires of self-stimulatory behavior and the emergence of dominant topographies indicate response selection and strengthening, which require the action of some mechanism. Perceptual reinforcement is hypothesized to be that mechanism because two basic functions of operant reinforcement are response strengthening and response selection or differentiation (Skinner, 1969).

In the absence of intensive intervention, high levels of self-stimulatory behavior and the lack of alternative behavior interact to exacerbate each other. High-rate self-stimulatory behavior may prevent or delay learning of alternative behaviors (the blocking effect) and the continued absence of alternative behaviors renders perceptual reinforcers continually powerful, maintaining high rates of self-

stimulatory behavior that continue to impair learning, and so on. Over time, a large number of factors may come to influence self-stimulatory behavior to varying degrees, as shown in ecological and behavioral studies, but such variables are rarely powerful or consistent enough to override completely the perceptual reinforcement that maintains the behavior at some strength indefinitely. To date, the only treatment strategy showing long-term effectiveness begins early in childhood and incorporates both intensive teaching of alternative behaviors and consistent suppression of self-stimulatory behaviors (Lovaas, in press).

The foregoing account is necessarily speculative at this time, but its main features have considerable indirect support and are readily disconfirmable by appropriate tests. For example, longitudinal research on the early course of self-stimulatory behavior in severely or profoundly retarded and autistic children prior to treatment would indicate the degree to which Thelen's (1979, 1980, 1981) findings with normal infants are generalizable to this population, and "sensory extinction" manipulations (Rincover, 1978) in infancy and early childhood could elucidate the role of perceptual consequences in early self-stimulatory behaviors. Further, experimental models for the changes described here exist in demonstrations of transitions from reflexive to operant control of behaviors such as leg-kicking, walking, and smiling in normal infants (Rovee-Collier & Gekoski, 1979; Zelazo, 1976).

At present, we are aware of only two sets of data that may impose some qualifications on this account. Berkson et al. (1985) surveyed the parents and teachers of 223 developmentally disabled children under 3 years of age in early intervention programs and found that only about 16% of the "profoundly" disabled children were reported to engage in "abnormal, repetitive and/or self-stimulatory behaviors." Perceptual reinforcement theory would predict that virtually all such individuals (except those with significant motor handicaps) would engage in self-stimulatory behavior. Possible reasons for the low prevalence obtained by

Berkson *et al.* (1985) may include problems in communicating adequate definitions of self-stimulatory behavior to parents and teachers in a questionnaire, the resulting likelihood that they would report only very frequent and salient topographies, individual differences in motor development that delayed the appearance of self-stimulatory behaviors beyond the first 2 years in some cases, and the probability that the children's early intervention programs provided enriched environments, teaching of appropriate alternative behaviors, and discouragement of self-stimulatory behaviors.

In the second study, Schwartz *et al.* (1986) found that body-rocking and hand-gazing in retarded toddlers showed some significant topographical differences from these behaviors in normal infants matched on developmental age with the Bayley Scales. For example, retarded toddlers rocked more times in each bout and exhibited greater amplitude (back and forth excursion) than normal infants. They concluded that the abnormal stereotypies of retarded children may therefore not develop out of the normal repetitive behaviors of infancy. However, as the authors noted, the differences found were based on only one developmental point and may not have existed from the beginning of development. Further, such a conclusion rests on a strict developmental (maturational) view of self-stimulatory behavior and ignores learning that may not be reflected in Bayley scores. Developmental matching resulted in retarded toddlers of 19 to 24 months being compared with normal infants of 4 to 9 months. Thus, the older chronological ages of the retarded children may account for the obtained differences because it allowed more opportunity for perceptually reinforced practice of self-stimulatory behaviors. As suggested above, the perceptual reinforcement of self-stimulatory behaviors and the paucity of alternative behaviors in severely impaired children should result in their self-stimulatory behaviors rapidly becoming more intensive than and topographically different from those of normal infants.

In the review that follows, a number of studies with practical as well as theoretical significance are presented. First, we examine studies that document

the reinforcing function of a variety of sensory and perceptual stimuli. Next, we review studies that demonstrate the reduction (extinction) of self-stimulatory behaviors when their perceptual consequences are removed. An additional group of studies, showing the inverse relationship between self-stimulatory and other behaviors, maintained by different reinforcers, are then discussed. Next, we present findings showing the interference or blocking effect that self-stimulatory behavior exerts over the acquisition of new behaviors. We then discuss studies on response substitution within self-stimulatory repertoires and, finally, studies documenting a biological need for stimulation from the literature on sensory deprivation.

### SENSORY AND PERCEPTUAL REINFORCEMENT

There are ample data to support the contention that sensory and perceptual events can function as reinforcers when made contingent on responding. In an early study, Girdner (1953) found that lever-pressing in rats increased with contingent changes in illumination. This finding was substantiated and elaborated in several subsequent studies, giving rise to the concept of sensory reinforcement (Fowler, 1971; Kish, 1966). Research on visual reinforcement was followed by a large number of studies with various animal species demonstrating the reinforcing properties of stimulation in other sense modalities, including audition, kinesthesia, gustation, olfaction, and touch. Kish (1966) reviewed this work and concluded that reinforcing forms of stimulation may be found in many sensory modalities and that the stimulus modalities in which sensory reinforcers will be found will vary across species.

Numerous studies support the notion that complex perceptual events may also serve as reinforcing stimuli. The large body of research on "curiosity" and "exploratory" drives first published 20 to 30 years ago qualifies for an interpretation in terms of perceptual reinforcement because of the complexity of the stimuli used as reinforcers, including novel objects, puzzles, views of the laboratory, moving

electric trains, etc. (Berlyne, 1960; Butler, 1953; Harlow, Harlow, & Meyer, 1950).

Studies on perceptual reinforcement with humans have yielded results comparable to the animal data. In several studies, illumination or color pattern changes contingent on various simple responses resulted in large increases in response rates in infants and preschool children (e.g., Antonitis & Barnes, 1961; Caron, 1967; Rheingold, Stanley, & Doyle, 1964; Rovee & Rovee, 1969; Stevenson & Odom, 1961). The reinforcing properties of some visual stimuli decreased over time, but small changes reinstated high rates of responding (Antonitis & Barnes, 1961). Many additional studies have demonstrated a perceptual reinforcement effect in older children and adults and have extended the range of perceptual consequences found to be reinforcing and the responses susceptible to reinforcement. Response-contingent presentation of shapes, words, patterns of lights, pictures, movies, and music will all reinforce both innate and arbitrarily selected behaviors (e.g., Benton & Mefferd, 1967; Cotter, 1972; Mira, 1968; Siqueland, 1968). The relationship of this research to self-stimulatory behavior is especially close in the case of those studies (e.g., Mira, 1968; Rovee & Rovee, 1969) that used conjugate reinforcement procedures (Lindsley, Hobika, & Etsten, 1961). In conjugate procedures, the frequency, intensity, or duration of the reinforcement varies directly with the rate, intensity, or duration of the response, just as the perceptual reinforcers of self-stimulatory behaviors vary directly with response characteristics. For example, Rovee and Rovee (1969) used the conjugate technique in perhaps its simplest form by tying a string from a mobile to an infant's leg. Leg flexions thus controlled movements of the mobile very directly and subsequent increases in leg flexions were observed.

Further studies supporting perceptual events as reinforcing stimuli may be found in the area of infant perception. If it is assumed that infants' visual fixations are reinforced by what they see, the literature suggests that complex and patterned stimuli are more reinforcing than stimuli possessing fewer of those qualities (e.g., Berlyne & Bou-

dewijns, 1971; Nelson & Kessen, 1969; Salapatek, 1968).

The operation of perceptual reinforcement has also been demonstrated with retarded and autistic children (reviewed by Murphy, 1982). Some of the findings with autistic children include the following: Frankel, Freeman, Ritvo, Chikami, and Carr (1976) found that a flickering light functioned as a reinforcer for lever pulls and Freeman, Frankel, and Ritvo (1976) showed that rocking in an automated rocking chair reinforced button presses. Rincover, Newsom, Lovaas, and Koegel (1977) studied three types of stimulation: music, visual flicker, and visual movement. In each condition, one of these three stimuli was presented contingent on the child's bar pressing, resulting in high and durable rates of responding. Once satiation occurred on a particular stimulus, a small change in that stimulus could reinstate a high rate of responding, much as in the Antonitis and Barnes (1961) study. Interestingly, there were large individual differences in preference for certain perceptual consequences over others: what was reinforcing for one child was not reinforcing for others. Most recently, Rincover and Newsom (1985) directly compared the reinforcing effects of edible and perceptual reinforcers and found that multiple (varied) perceptual reinforcers maintained responding on classroom tasks over more trials than did multiple edible reinforcers. They also addressed the conceptual issue that, although all reinforcers provide sensory or perceptual stimulation, it is nevertheless useful to retain sensory or perceptual reinforcement as a distinct term because such reinforcers have some unique properties that distinguish these stimuli from edibles, praise, etc.

Wolery (1978) capitalized on the idiosyncratic nature of perceptual reinforcers to teach preacademic tasks. He first observed the topographies of two autistic children's self-stimulatory behaviors in a preschool classroom, then provided equivalent stimulation as a sensory consequence for correct responding. For one child, the experimenter's brief pats on the leg functioned as a positive reinforcer; for the other, rubbing the arm did the same. Finally, studies have shown that self-stimulatory be-

havior itself is reinforcing. Hung (1978) found that allowing autistic children to earn tokens for engaging in appropriate speech and then to exchange those tokens for brief periods of self-stimulatory behavior resulted in increased rates of appropriate speech. Wolery *et al.* (1985) showed that allowing autistic children to engage in 5 s of one of their self-stimulatory behaviors after each correct response resulted in acquisition of various classroom tasks.

In order to argue that self-stimulatory behavior may be acquired on the basis of contingent perceptual reinforcement, it would be most convincing to demonstrate that self-stimulatory behaviors could be shaped experimentally by the use of the relevant perceptual reinforcers. Unfortunately, such a study has not been undertaken successfully, perhaps because of the difficulty in achieving external experimental control over the functional perceptual reinforcers involved, which normally are inside of or closely controlled by the person engaging in self-stimulatory behaviors.

In summary, evidence for the existence of perceptual reinforcement as a behavior process is sufficient to conclude that a wide variety of experimental perceptual stimuli are capable of strengthening and maintaining arbitrarily selected responses studied in laboratory and classroom situations. By inference, then, response-generated perceptual stimuli seem likewise capable of reinforcing self-stimulatory responses in the natural environment. Thus, the primary importance of the literature on perceptual reinforcement is that it indicates the behavioral process whereby the stimuli generated by self-stimulatory behavior can be conceptualized as motivational events that select, strengthen, and maintain these behaviors.

### SENSORY EXTINCTION

If perceptual consequences reinforce self-stimulatory behaviors, the behaviors previously maintained by such consequences should decrease in strength when the consequences are removed. That is, the behavior should exhibit extinction. Studies of this type have been conducted by Rincover and

his colleagues, who described the process as one of "sensory extinction" (Rincover, 1978). Working with autistic children who showed high rates of object-spinning, hand-flapping, and object-twirling, Rincover systematically removed the auditory, visual, or proprioceptive feedback thought to reinforce the various behaviors. For example, for a child who spun objects on a table, the auditory consequences were removed by carpeting the table and, in another condition, the visual consequences were removed by blindfolding the child. The behaviors decreased dramatically when the auditory stimuli were removed, only to recover to full strength when the auditory stimuli were reintroduced. Significantly, removing the visual consequences did not affect the behavior. Apparently, the critical modality of stimulation may not be apparent to casual observation, but must be isolated through experimental manipulation. These findings were replicated in subsequent studies by Rincover and his associates (Rincover, Cook, Peoples, & Packard, 1979; Rincover & Devany, 1982; Rincover, Newsom, & Carr, 1979) as well as by others (Aiken & Salzberg, 1984), and are critical because they demonstrate a direct functional relationship between self-stimulatory behaviors and their perceptual consequences. The importance of the sensory extinction effect has been summarized by Berkson: "It sometimes is possible, therefore, both to demonstrate that the stereotyped behavior is self-stimulatory and to specify the nature of the self-stimulation" (1983, p. 244).

Significantly, self-stimulatory behaviors do not extinguish with the removal of social reinforcers. When subjects are left unattended, the rate of their self-stimulatory behavior remains high. This independence of social reinforcement is documented in studies with both retarded and autistic subjects, showing that self-stimulatory behavior gives no evidence of extinction in settings that are devoid of social reinforcement (Berkson & Mason, 1963, 1964b; Lovaas *et al.*, 1977; Newsom, 1974; Ritvo, Ornitz, & LaFranchi, 1968). Self-stimulatory behavior is impervious to social extinction even when there is clear evidence of the social extinction of other, more adaptive behaviors in the same sub-

jects (Lovaas et al., 1965; Lovaas, Koegel, Simmons, & Long, 1973; Lovaas et al., 1977).

### THE INVERSE RELATIONSHIP

Further support for the perceptual reinforcement hypothesis can be found in a large number of studies on the inverse relationship between self-stimulatory and alternative behaviors. In general, these studies show that when self-stimulatory behaviors are strong, alternative behaviors are weak, and vice versa. Such data support a reinforcement interpretation of self-stimulatory behaviors because behaviors that are controlled by a strong reinforcer tend to dominate behaviors based on a weak reinforcer. For example, for a hungry organism, food as a reinforcer would increase eating and food-seeking behaviors, whereas other behaviors, based on relatively weaker reinforcers, would decrease in strength. The literature on performance under concurrent schedules of reinforcement is relevant here. A large number of basic studies have established that organisms allocate the time they spend engaging in various behaviors according to the relative rates, amounts, or qualities of reinforcement available for each behavior (a recent review of the work at the human level appears in Pierce & Epling, 1983). By extension, the inverse relationship existing between self-stimulatory behaviors and alternative behaviors may result from the competition between perceptual reinforcers and other kinds of reinforcers in gaining control over the individual's performance. In most situations, perceptual reinforcers will be more powerful for severely developmentally disabled persons, as indicated by the amount of time allocated to self-stimulatory behavior. In certain situations, however, different reinforcers will temporarily be prepotent as the result of, for example, varying levels of deprivation (Lovaas, Litrownik, & Mann, 1971).

Studies showing that the strength of self-stimulatory behavior is inversely related to the strength of alternate behaviors fall into three groups. First, several studies have shown that edible and social reinforcement of alternate behaviors (such as toy play and bar pressing) reduces self-stimulatory be-

havior in both retarded (Favell, 1973; Greer, Becker, Saxe, & Mirabella, 1985; Hollis, 1978; Mulhern & Baumeister, 1969) and autistic persons (Ackerman, 1980; Eason, White, & Newsom, 1982; Koegel & Covert, 1972; Runco, Charlop, & Schreibman, 1986). It is noteworthy that the self-stimulatory behaviors usually returned to full strength when the experimental reinforcers for the alternate behaviors were withdrawn.

A second, generally less successful method for reducing self-stimulatory behavior is simply to provide subjects with opportunities to engage in alternative behaviors by enriching previously barren environments, providing objects to manipulate, and by providing the opportunity for social interaction (Berkson & Mason, 1963, 1964b; Davenport & Berkson, 1963; Favell, McGimsey, & Schell, 1982; Guess & Rutherford, 1967; Horner, 1980; Levy & McLeod, 1977; Moseley, Faust, & Reardon, 1970; Murphy, Carr, & Callias, 1986; Rincover et al., 1979).

Some of the findings with object manipulation show that the relationship between the type of sensory feedback the objects provide and the individual's self-stimulatory behavior can be crucial. Rincover et al. (1979) found that autistic children selectively played with toys providing feedback similar to that provided by their self-stimulatory behaviors; the children did not play with toys providing feedback in another modality. Further, play with the appropriate toy replaced self-stimulatory behavior in the absence of extrinsic reinforcement for toy play or constraints on self-stimulatory behavior. Similarly, Favell et al. (1982) reduced repetitive, stereotyped self-injurious behavior by giving the subjects toys that provided stimulation in the same modality as the self-injurious behavior (e.g., play with a toy prism replaced eye-poking). The results obtained in both studies may be attributable to functional equivalence between the perceptual stimulation provided by the toys and the self-stimulatory behaviors.

Finally, the reciprocal relationship between self-stimulatory and alternate behaviors has also been investigated in studies of behavioral limitations of one kind or another. High levels of self-stimulatory

behavior have been found to be associated with low intelligence (Berkson & Davenport, 1962; Guess, 1966), younger chronological ages (Kravitz & Boehm, 1971; Mitchell & Etches, 1977; Thelen, 1979), visual impairment (Berkson, 1964; Berkson & Davenport, 1962; Berkson & Karrer, 1968; Guess, 1966; Thurrell & Rice, 1970), non-ambulation (Guess, 1966), institutionalization (Dennis & Najarian, 1957; Kaufman, 1967), crib confinement in children (Warren & Burns, 1970) and isolation rearing in primates (Davenport & Menzel, 1963; Harlow & Harlow, 1962). All of these subject and setting variables have in common the restriction of opportunities for engaging in alternative behaviors. Under such conditions, some individuals apparently compensate for the resulting lack of stimulation by engaging in self-stimulatory behaviors (Berkson & Mason, 1963).

These three groups of studies document the inverse relationship between self-stimulatory behavior and other, alternative behaviors. The first two groups show that extrinsic reinforcement and stimulating environments or objects increase alternative behaviors and decrease self-stimulatory behavior. In these studies, the interaction between alternate and self-stimulatory behaviors was not likely due to mechanical incompatibility, because most observations were made in such a way that it was possible for subjects to engage in both classes of behavior in each session. The fact that they did not supports an interpretation in terms of competing reinforcers: Sufficiently powerful extrinsic reinforcers or reinforcing activities can temporarily override the perceptual reinforcement available in self-stimulatory behavior. The third group of studies shows that biological or environmental constraints on alternative behaviors may leave individuals little choice but to engage in self-stimulatory behavior.

### THE BLOCKING EFFECT

One characteristic that is particularly significant for teachers and therapists of the developmentally disabled is the blocking or retarding effect of self-

stimulatory behavior on the acquisition of alternative behaviors. The theoretical basis for the blocking effect was expressed in an earlier article (Lovaas *et al.*, 1971), where it was postulated that for autistic and retarded children, the reinforcing stimuli generated by self-stimulatory behavior may be so strong relative to the extrinsic reinforcers controlled by the therapist or teacher that such extrinsic reinforcers may be relatively ineffectual. As a result, perceptual reinforcers control the individual's attention to such a degree that he or she attends minimally or not at all to external stimuli. In operant terms, the perceptually reinforcing stimuli exert strong stimulus control over the person's feeling, looking, and listening behaviors, perhaps because of variables such as salience and predictiveness, as studied in the areas of "blocking" and "overshadowing" (e.g., Mackintosh, 1977; Pavlov, 1927).

In a study comparing response latencies to auditory stimuli between normal and autistic children, long latencies (and failure to respond) occurred with autistic children only when the auditory stimulus was presented while these children were engaged in self-stimulatory behavior, and did not occur in the absence of such behavior (Lovaas *et al.*, 1971). Similar blocking effects have been reported in a study on level of object manipulation in mentally retarded persons (Berkson & Mason, 1964b). Low levels of object manipulation were noted only during intervals of self-stimulatory behavior. It was concluded that lowered responsiveness to the environment may not be a general characteristic of retarded individuals but may be mainly associated with self-stimulatory behavior.

Another study dealt more directly with the blocking effects of self-stimulation on a discrimination learning task with autistic children (Koegel & Covert, 1972). Either the discrimination was acquired early in training, with a concurrent, spontaneous reduction in self-stimulatory behavior, or the subjects made no progress over hundreds of trials until their self-stimulatory behaviors were suppressed by the experimenter, which then allowed for quick acquisition of the discrimination task.

Additional studies give further data on the therapeutic effect of experimentally suppressing self-stimulatory behaviors in order to render subjects more receptive to the reinforcers available for engaging in appropriate alternative behaviors. In one study, autistic subjects were first taught to play with toys through food reinforcement (Koegel et al., 1974). Once toy play had been established, food reinforcement was withdrawn, which was accompanied by a decrease in toy play and an increase in self-stimulatory behavior. The subjects' self-stimulatory behaviors were then punished, which resulted in a concurrent increase in appropriate play. Finally, when the self-stimulatory behavior was no longer suppressed, it increased in strength and appropriate play behavior again decreased to presuppression levels. Similar data have been reported by Lovaas, Freitag et al. (1966) and Risley (1968).

A recent study (Ackerman, 1980) dealt with the blocking effect of self-stimulatory behavior on the learning of appropriate social behaviors. Young autistic subjects received extensive behavioral treatment in their homes to increase socially meaningful behaviors, such as language and play, during a massive positive reinforcement program that included more than 40 hours per week of one-to-one teaching. The treatment produced increases in socially appropriate behaviors and a concurrent reduction in self-stimulatory behaviors. However, the gains in social behavior remained very unstable and the self-stimulatory behaviors were not fully suppressed, even after several months of treatment, until the self-stimulatory behavior was punished. Self-stimulatory behaviors quickly decreased, accompanied by concurrent rapid and stable gains in socially appropriate behaviors. This study, perhaps more than any other, suggests that the perceptual reinforcers that maintain self-stimulatory behaviors may be so strong as to interfere with even the most intensive attempts to teach alternative, socially appropriate behaviors solely through positive reinforcement. The fact that the children did acquire some new behaviors prior to punishment indicates that there are some limitations on the blocking effect, as might be expected. Further indications

are provided by studies showing that higher-functioning autistic children (i.e., those with some speech) may learn simple discriminations while engaging in self-stimulatory behavior (Chock & Glahn, 1983; Kiler & Harris, 1977; Lovaas et al., 1971). But for more severely developmentally disabled children, food and social reinforcers often compete very poorly with perceptual reinforcers.

## RESPONSE SUBSTITUTION

Additional understanding of the motivation behind self-stimulatory behavior can be obtained by manipulating one self-stimulatory response and observing the effect on other self-stimulatory responses. The logic of such an intervention is that if two or more behaviors are controlled by the same class of reinforcers, then the suppression of one behavior should lead to an increase in the strength of one of the other behaviors. Thus, Newsom (1974) suggested that in an environment where there is no extrinsic reinforcement for any behavior, the elimination of one self-stimulatory behavior from a person's repertoire should lead to an increase in the strength of another self-stimulatory behavior if the stimulation that each provides functions as an intrinsic perceptual reinforcer. In Newsom's study, the frequency of several self-stimulatory behaviors was recorded for each of four severely retarded, autistic subjects during a baseline condition. The temporary suppression of one dominant self-stimulatory behavior (e.g., rocking) simultaneously brought an increase in another self-stimulatory behavior (e.g., hand-flapping). These data are consistent with at least two other studies. Rollings, Baumeister, and Baumeister (1977) used overcorrection to reduce one kind of high-rate, self-stimulatory behavior (body-rocking), only to observe a concurrent increase in head-nodding, a self-stimulatory response that previously had occurred at low rates. Harris and Wolchik (1979) observed an increase in head-nodding after suppressing hand movements with overcorrection in one of their autistic subjects.

A recent study (Epstein et al., 1985) is noteworthy because it reports data on changes in re-

sponse interaction among self-stimulatory behaviors over rather long time periods (up to 7 years) in six autistic children undergoing intensive behavioral treatment. In this study, various kinds of self-stimulatory behaviors were classified according to levels of complexity, starting with low-level self-stimulation involving the body only (as in rocking and pacing), to levels involving simple interaction with objects (as in repeated tapping, spinning, lining of objects in rows), through intermediate levels (such as repeatedly assembling and reassembling the same puzzle, developing echolalic speech, prolonged repetition of single words or phrases), to relatively high levels, as when a child compulsively insisted on spelling words, spent a major part of his day correcting clocks to achieve synchronous time, insisted on counting objects, etc. The six subjects started treatment exhibiting the same low level of self-stimulatory behavior, but the four subjects who improved the most in treatment also moved to higher levels of self-stimulatory behavior. The higher forms were never taught or reinforced by others; rather, they emerged spontaneously after lower forms were suppressed and the children learned basic language and academic behaviors. These "generative" self-stimulatory behaviors apparently reflected the children's increasing susceptibility to reinforcement by complex perceptual stimuli as their treatment progressed. Existence of these behaviors suggests that a meaningful goal of treatment may be the substitution of higher levels of self-stimulation for lower levels.

### SENSORY DEPRIVATION EFFECTS

A final group of studies provides evidence for considering perceptual reinforcers as primary reinforcers that, like food and water, fulfill a biological function or need of the organism. This work demonstrates the deleterious effect of the deprivation of sensory and perceptual stimulation, effects that are analogous to the deprivation of other need-satisfying stimuli and include changes in the neurophysiology of the deprived organism. A thorough review of this diverse area is beyond the scope of this paper, but a few examples of research show-

ing a clear biological change as a result of sensory deprivation and, inferentially, a biological need for stimulation, will be mentioned.

Long-term deprivation usually results in more severe and longer lasting effects than does short-term deprivation, with changes in brain anatomy that are specific to the type of deprivation experienced. That is, restricted visual stimulation produces retarded neuronal development in the visual cortex of the brain and restricted auditory stimulation produces retarded development of the temporal auditory cortex (e.g., Greenough, Volkmar, & Juraska, 1973; Wiesel & Hubel, 1965). Similarly, rearing animals in isolation and in impoverished environments also produces neurological damage, even though the subject has total functioning of all its sensory apparatus (Riesen, 1975). For example, differences in brain anatomy and chemistry have been found between rats reared in experimentally enriched environments and litter mates who were reared in isolation in experimentally impoverished environments (Krech, Rosenzweig, & Bennett, 1966).

Short-term deprivation also produces significant changes, including hyperactivity or hyperexcitability (Sprague, Chambers, & Stellar, 1961), and changes in the motivational properties of various sensory inputs (Fox, 1962; Sackett, 1966). Thus, previously neutral and even aversive stimuli have been shown to take on reinforcing value following periods of sensory and perceptual deprivation (Harris, 1969; Lichstein & Sackett, 1971). Susceptibility to sensory input is also changed (usually increased) following periods of deprivation (Cummins, Walsh, Budtz-Olsen, Konstantinos, & Horsfall, 1973).

Research on the effects of sensory and perceptual deprivation shows that organisms seem to need sensory and perceptual stimulation in a biologically significant sense (Heron, 1957). Without it, they will experience various kinds and degrees of structural damage which seem to increase as a function of the severity of the deprivation. The effects of sensory deprivation appear closely analogous to the deprivation effects of other primary reinforcers, such as food and water. A theoretical implication of

these studies is that a person with severe physical, behavioral, or environmental limitations, lacking a repertoire of behaviors that could provide normal amounts and kinds of stimulation, develops self-stimulatory behaviors because they provide necessary sensory and perceptual stimulation to the central nervous system. The studies point to the biological wisdom of engaging in self-stimulatory behavior to maintain adequate central nervous system functioning: A developmentally disabled person may need self-stimulatory behavior much like he or she needs food. The studies therefore imply the importance of allowing individuals access to self-stimulatory behaviors when the development of alternative behaviors is not possible. The qualification at the end of that sentence is very important; we are not advocating an excuse for failure to treat self-stimulatory behavior. However, in certain situations, such as during periods when the individual is allowed privacy, or in severely understaffed, barren institutional wards with inadequately trained personnel, punishing self-stimulatory behavior without also teaching and reinforcing appropriate alternatives would seem simply to constitute unnecessary and possibly harmful harassment, as well as probably being ineffective.

## DISCUSSION

We have described a class of high-rate behaviors that are stereotyped, repetitive, and appear to be autonomous of social contingencies. These stereotyped motor acts or self-stimulatory behaviors can be understood in terms of operant learning theory if it is recognized that these behaviors can be selected, strengthened, and maintained by perceptual reinforcers that are closely controlled by the organism itself. Our hypothesis relates to a long history of theoretical concern with such functionally autonomous behaviors in psychology, as exemplified in Piaget's (1952) concept of the secondary circular reaction and Allport's (1961) observations on perseverative behaviors. Currently, some theoretical discussions of the nature of reinforcement propose that a wider range of behavioral phenomena than those commonly studied in animal laboratories may

be explained if the stimulation generated by certain responses is understood as having reinforcing properties. Thus, Herrnstein (1977) argues that further progress in psychological knowledge will require an appreciation of the complexity of the "motivational endowment" of organisms and the study of "the reinforcing status of the stimuli arising in behavior" (p. 610). Similarly, Vaughan and Michael (1982) suggest that a variety of everyday behaviors can be understood in terms of Skinner's concept of "automatic" reinforcement, which they define as "reinforcement that is not mediated by the deliberate action of another person . . . . It is a 'natural' result of behavior when it operates upon the behavior's own body or the surrounding world" (p. 219). Most relevant in the present context is their discussion of "the behavior of producing," or engaging in a behavior in order to perceive (feel, hear) its automatic consequences. One example they cite is provided by Skinner's observation, "The student may be automatically reinforced as he picks out a familiar tune on the piano . . ." (1968, p. 209).

## *Alternative Theories*

To date, most accounts of self-stimulatory behavior have emphasized developmental, physiological, or ethological concepts and have focused on its structure, situational determinants, or biological substrates. The merits and limitations of these accounts have been discussed by recent reviewers (Berkson, 1983; Lewis & Baumeister, 1982; Newsom, Carr, & Lovaas, 1979; Romanczyk, Kistner, & Plenis, 1982). However, two concepts require a closer look than they have previously received because they seem to be alternatives to the theory presented here. One—arousal—appears in one form or another in numerous accounts of self-stimulatory behavior; the other—neural oscillators or "pattern generators"—is representative of many efforts to identify a neurological basis for self-stimulatory behavior. Although it is important for explanations of any behavioral phenomenon to be pursued at multiple levels of analysis, these approaches appear to have serious theoretical limitations and have been comparatively sterile in gen-

erating intervention strategies, considerations that partly justify proposing the present hypothesis.

**Arousal.** Theories appealing to physiological arousal as an intervening variable have differed primarily in terms of the scope of the phenomena they attempt to explain and the function they assign to arousal. "Elicitation" accounts have focused on transient increases in self-stimulatory behavior accompanying various "drive" and "frustration" manipulations (e.g., Forehand & Baumeister, 1971; Levitt & Kaufman, 1965). Broader "modulation" theories have addressed the long-term maintenance of self-stimulatory behavior in homeostatic terms (e.g., Hutt & Hutt, 1968; Zentall & Zentall, 1983). Evidence offered in support of the elicitation function of arousal in humans comes from studies showing that self-stimulatory behavior increases with the noncontingent presentation of loud sounds, physical restraint, and frustration procedures such as the prevention or extinction of food-reinforced behaviors and the interruption of eating (reviewed most comprehensively by Romanczyk *et al.*, 1982). There are a few contradictory findings in this literature, however, that cast doubt on the predictive power of the arousal concept. For example, food deprivation, a classic drive-inducing manipulation that reliably increases self-stimulatory behavior in chimpanzees (Berkson & Mason, 1964a), has inconsistent and equivocal effects in humans (Hollis, 1973; Kaufman & Levitt, 1965). Loud noise may show inexplicable sex differences, increasing rocking in males and decreasing rocking in females (Levitt & Kaufman, 1965). Physical restraint fails to increase subsequent rocking if the arms and hands are left free (Higenbottam & Chow, 1975), presumably allowing substitute self-stimulatory behaviors to occur.

Aside from the existence of some contrary findings, there are three major problems with elicitation theories. First, none of the studies provided evidence that arousal, when it occurs, actually elicits rather than simply coincides with increased self-stimulatory behavior as an interesting but causally unimportant epiphenomenon. Second, the explanations of the findings in terms of arousal are un-

parsimonious relative to a simpler alternative account. Note that all of the operations listed above have been or could readily be shown to be aversive in independent tests of their ability to motivate escape responding. Thus, the studies described simply indicate the existence of a functional relationship between noncontingent aversive stimuli and increases in self-stimulatory behavior. This alternative account, in addition to dispensing with arousal as an intervening variable, has the advantage of being easier to test. That is, it is far easier to establish whether or not a stimulus is aversive using common operant escape or avoidance paradigms than it is to establish whether or not it produces physiological arousal, given the difficulties in operationalizing arousal (*cf.* Zentall & Zentall, 1983). The third major problem with the elicitation account is that it deals with only transient stimulus effects and fails to address the etiology or long-term maintenance of self-stimulatory behavior (Berkson, 1983).

Arousal modulation theories derive from the concept that organisms strive to maintain an optimal level of arousal or stimulation (Duffy, 1962; Hebb, 1955; Leuba, 1955). Theorists in this area have concentrated on autistic children and have proposed that their self-stimulatory behavior represents an attempt to lower chronic overarousal (Hutt & Hutt, 1968) or overstimulation (Zentall & Zentall, 1983) by producing repetitive, monotonous internal stimulation that blocks exteroceptive stimulus input. Earlier, we reviewed the blocking effects of self-stimulatory behavior. However, the premise that autistic children are chronically overaroused or overstimulated remains to be demonstrated. It is not clear how arousal and stimulation should be measured to test these theories, but the following findings appear to contradict them. First, cortical EEG abnormalities occur in 40% to 60% of autistic children (Hermelin & O'Connor, 1970; Small, 1975; Tsai, Tsai, & August, 1985) but the types of abnormalities vary greatly across children and do not consistently indicate overarousal. Second, when arousal is measured by electrodermal activity (skin conductance level) or heart rate, the findings are contradictory, with some

studies suggesting overarousal (Palkovitz & Wiesenfeld, 1980; Sroufe & Waters, 1977) but others, using more controls, failing to find evidence for overarousal (Bernal & Miller, 1971; Stevens & Gruzelier, 1984; van Engeland, 1984). Third, specifically regarding overstimulation, studies of cardiovascular changes (e.g., Kootz & Cohen, 1981) and auditory evoked brainstem responses (e.g., Gillberg, Rosenhall, & Johansson, 1983) indicate inattentiveness to most exteroceptive stimuli and delayed transmission of auditory stimuli in lower functioning autistic children. Although some of these findings have been viewed as learned avoidance responses to overstimulation (Kootz, Marinelli, & Cohen, 1982), it is equally possible that they are due to neurological defects that limit sensory intake (Tanguay & Edwards, 1982) and thus may preclude normal, much less excessive, stimulation.

*Neural pattern generators.* The highly rhythmic nature of self-stimulatory behaviors led Wolff (1967) to suggest that they were controlled by neural oscillators, or pattern generators. Pattern generators are "prewired" circuits in the central nervous system controlling rhythmic behaviors such as locomotion and mastication. Once triggered, they fire at a rhythmic rate that can be maintained in the absence of sensory feedback (Delcomyn, 1980; Grillner & Wallen, 1985). Sensory input may modulate somewhat the output of a pattern generator but has no role in the maintenance of its activity once initiated.

The possibility of neural pattern generators for self-stimulatory behaviors is suggested most directly by studies showing that (a) self-stimulatory behaviors tend to occur at fixed rates within and sometimes across individuals (e.g., one per second for body-rocking and three to four per second for hand-flapping: Ritvo et al., 1968; Walker & Coleman, 1976); (b) most bouts of body-rocking and head-rolling last 5 s or less (Lewis, MacLean, Johnson, & Baumeister, 1981); and (c) no systematic trends occur across the day in number of bouts, mean bout durations, or bout duration variability (Lewis et al., 1981).

Although hypothetical neural pattern generators

can account for these findings, certain other relevant considerations suggest alternative possibilities. Rhythm and stereotypy do not necessarily mean a behavior is driven by a pattern generator instead of being learned. Constancies in response rate as well as duration and variability of bouts are characteristic of steady-state performance on schedules of food reinforcement (Blough, 1963). As Thorndike (1898) first observed and Zeiler (1977) has recently emphasized, "The production of repetitive stereotyped behavior is the defining attribute of reinforcement . . ." (Zeiler, 1977, p. 204), a statement that presumably holds for perceptual as well as food reinforcement. Second, it is impossible to account for sensory extinction effects if pattern generators in humans, like those in lower organisms, are assumed to make only minor adjustments to sensory feedback. In fact, exteroceptive and peripheral stimuli modulate the activity of all motor circuits to an increasingly greater extent going up the phylogenetic scale (Knoback & Demarest, 1981, pp. 196–197; Stein, 1978). One could still argue for a weak pattern generator theory, allowing a greater role for sensory feedback at the human level, but doing so would result in blurring and probably losing the conventional distinction between pattern generators as innate neurological oscillators and other motor circuits. A better alternative would be to propose acquired "motor programs" that control overlearned, high-rate motor behaviors in the absence of feedback (Dickinson, 1974). However, such circuits could only account for the terminal rates of self-stimulatory behaviors (cf. Laszlo & Bairstow, 1971), leaving unexplained their acquisition and again failing to account for sensory extinction effects.

Finally, we must note that studies of the structural aspects of self-stimulatory behaviors tend to focus on only one or two dominant behaviors and collapse various topographies of each behavior together for recording purposes. Such manipulations are certainly appropriate in the context of these studies, but they thereby exclude information that could be valuable in understanding the function of self-stimulatory behavior. As we suggested earlier, the variability in self-stimulatory topographies and

the number of different behaviors observable in most autistic and retarded persons are just as important as the regularities observed in a few dominant behaviors because they help to account for the durability of this class of behaviors.

The focus on the stereotypy of self-stimulatory behaviors as their most important characteristic has led to many attempts to relate these behaviors to other stereotyped behaviors seen in lower animals. Thus, attention has generally been directed down the phylogenetic scale to isolation-rearing stereotypes, cage stereotypes, fixed action patterns, adjunctive behaviors, and invertebrate locomotion. Although often topographically similar to self-stimulatory behaviors in humans, these behaviors may be functionally different (cf. Berkson, 1967, 1983). It may be more productive to focus on another salient characteristic of self-stimulatory behaviors, their perceptual consequences, as proposed in this paper. Such a focus might redirect attention toward more complex behaviors of humans that are functionally related to self-stimulatory behavior by virtue of their dependence on perceptual reinforcement. In young children, for example, activities such as swinging, scribbling, looking into a kaleidoscope, pounding pegs with a mallet, private speech, and making rhythm-band music do not seem conceptually too far from what is now studied as self-stimulatory behavior. Examples of perceptually reinforced behaviors in adults may include recreational exercise, eating "tasty" or "gourmet" foods instead of merely nutritionally adequate foods, creating or looking at works of art, composing or listening to music, ingesting alcohol or other mood-altering drugs, smoking, or hallucinating. Certainly, other (e.g., genetic, social, cultural, economic) variables contribute to the control of such behaviors but their perceptual consequences also seem very important, if often taken for granted. Therefore, the continuum of greatest heuristic value may not be the one from self-stimulatory behaviors downward to topographically related animal behaviors but the one upward to functionally related human behaviors.

Before mentioning certain clinical and educational implications of the perceptual reinforcement

hypothesis, an additional point will be discussed briefly to further clarify our position and avoid possible misunderstanding. It is important to distinguish the hypothesis presented here from other self-stimulation theories. Sometimes the stimulation intrinsic to self-stimulatory behavior has been viewed solely as serving an arousal-enhancing function. It is then argued that the concept is circular, because the occurrence of self-stimulatory behavior must depend on a nonstimulating environment, which in turn can be identified only if self-stimulatory behaviors are occurring there (Baumeister, 1978). Although we have mentioned the evidence indicating a biological function for stimulation and suggested that this characteristic of organisms might be the ultimate reason for the reinforcing properties of perceptual stimuli, our case does not require inadequate stimulation as a precondition. Self-stimulation as a motivational variable can be discussed at the behavioral level in terms of the well-established empirical concept of sensory reinforcement. Operations that reduce the level of stimulation available from the environment may enhance the potency of self-stimulation as a reinforcer, and thus lead to increased rates of the behavior, but self-stimulation retains reinforcing properties in both stimulating and nonstimulating environments.

### *Clinical and Educational Implications*

The main advantage of conceptualizing self-stimulatory behavior as operant behavior lies in the improved control that clinicians and teachers may be able to exercise over such behavior. We reviewed studies showing that control over self-stimulatory behavior can be achieved either directly through the removal of the perceptual reinforcers underlying the self-stimulatory behavior when these are accessible (sensory extinction), or indirectly, by strengthening alternative behaviors. The opportunity to engage in self-stimulatory behavior also can be used as reinforcement for strengthening socially desirable behaviors, as demonstrated by Hung (1978) and Wolery et al. (1985). As Hung (1978) noted, "the controlled use of self-stimulation as reinforcement points to the possibility of enlarging

the reinforcement repertoire employed in the treatment of autistic children" (p. 365). Similarly, more extensive assessment of the usefulness of extrinsic perceptual reinforcers for teaching alternative behaviors is warranted (Murphy et al., 1986; Pace, Ivancic, Edwards, Iwata, & Page, 1985; Rincover & Newsom, 1985). Finally, a major avenue of clinical control yet to be fully explored may consist of changing the form of an individual's self-stimulatory behavior from motor forms to higher, more verbal or conceptual forms that begin to approximate normal behaviors, as suggested by Epstein et al. (1985). Studies in which simple forms of self-stimulatory behavior were replaced with appropriate play indicate the feasibility of at least the initial steps in such an effort (Eason et al., 1982; Favell et al., 1982; Greer et al., 1985; Rincover et al., 1979).

The extent to which the perceptual reinforcement hypothesis may lead to a better understanding of aberrant behaviors in clinical populations other than the developmentally disabled poses an interesting question. In 1911, Bleuler (1911/1950) gave a description of stereotypies in schizophrenic adults that is virtually indistinguishable from that given to developmentally disabled persons many years later. He described a wide range of motor behaviors, noting how they were "repeated incessantly with an almost photographic sameness" (p. 186). Of particular interest is his description of vocal and verbal stereotypies whose expression lasted for days or years: "... stereotyped yelling, screaming, roaring, . . . played with the same trill or chord . . . a thousand times in succession . . . . The same words or sentences . . . are repeated innumerable times . . . (such as) 'the crossed crux in a circumrex house' (Krapelin) are quite common" (p. 187). "... Stereotypies of thoughts and desires . . . (and) hallucinations are most obvious" (p. 189). Bleuler also noted the nonsocial character of such stereotyped behaviors ("... unrelated to context . . . without communicative intent" [p. 189]), their blocking effect on other behaviors ("... the stereotypies inhibit other actions" [p. 189]), and Lehmann (1980) commented on their inverse relation to other behaviors

("... social therapies that engage the patient in various activities . . . have robbed hallucinations of much of their vividness and persistence" [p. 1156]). The inverse relationship between hallucinations and alternate behaviors has also been confirmed experimentally (see Burns, Heiby, & Tharp, 1983, p. 135). The perceptual reinforcement hypothesis of self-stimulatory behavior may help direct future research to the potential reinforcing properties of hallucinatory behaviors and possible therapeutic interventions.

At a more general level, a final implication of our hypothesis is that self-stimulatory behavior may serve as a model for the study of many other conceptually related behaviors that do not conform to traditional experimental paradigms. Most analyses of learned behaviors have studied them as open systems (cf. Adams, 1971) in which experimenter-controlled inputs (antecedent and consequent stimuli) are related to defined outputs (responses) as discrete, sequential events. Self-stimulatory behavior represents a closed system in which the responses and reinforcers overlap temporally and spatially and are continuously interactive, maintaining each other indefinitely in the absence of any socially arranged contingencies. Many other behaviors seem to share these characteristics and may become more accessible to experimental analysis once reconsidered from this perspective.

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